

ROBOTIC MALE VAS DEFERENS INTRALUMINAL INJECTION SYSTEM

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Abstract-Delivering an injection correctly into the small diameter lumen of a tubular biological structure placed under the skin and not visible to the eye presents difficulties in medical practice. Suitable assist devices are currently not available. A new concept has been formulated to combine four modes of nonradiological imaging: scanning electrical impedance plethysmography; ultrasound; transillumination; and Moire topography to localize the subcutaneous biological structure. Image data is converted to a signal which controls an electro-mechanical device which assists the medical personnel's hand holding the injection syringe to approach the biological structure accurately. Force sensors are positioned at the base of the injection needle coupled to signal conditioning systems and piezoelectric tactile vibrators. Thereby enhanced perception of forces felt as each biological tissue layer is penetrated is obtained and the common problem of excessive penetration overcome. Design focuses on the specific application of delivering an injection into the vas deferens in the male scrotum for reversible contraception. The system may be adapted for injection into blood vessels.

Key Words: Injection; multimodal imaging; feedback electro-mechanical actuator

I. INTRODUCTION

Even with a high degree of skill positioning the tip of an injection needle accurately into the lumen of a tubular structure like the vas deferens of the male which has a lumen diameter of 0.6 mm is a difficult task [1]. The structure is not visible and often the structure is missed and/or the needle goes right through the structure [2]. Although the requirement is for the medical field there are no medical solutions. Hence technological problems of visualization through an opaque media, perception of low level graded forces and precision positioning have to be solved [3]. Furthermore since xrays are hazardous and xray scanning of the genital system is not permissible, the entire setup has to be nonradiological. The problem lies in finding the answers applicable to the present requirement and integrating the technologies underlying the answers into a total technology

package [3]. Since the item is required for routine usage on a mass scale, expensive general purpose imaging systems and manipulators cannot be brought into the system. The other facet of the problem therefore has been to design dedicated subsystems specifically for the task so that the overall system can be of reasonable cost and becomes a practically usable product.

As yet for routine medical care there is no guided injection system available. For the purpose of surgery there are image guided manipulators [4]. Generally these systems are based upon multiaxial xray images with robotic manipulators. Such guided systems amongst other areas have been used in brain surgery; surgery of the prostate, some gastrointestinal surgical tasks and some types of orthopaedic surgeries. Also more recently guided injections into the kidney and liver growths have been delivered. Multiaxial xray rules out the usage of these systems in the routine task of injections into the male vas deferens. Besides the cost and the cumbersome nature of the setup, the tissue contrast variations are not enough to enable use of the methodology for the subcutaneous injections. Multimodal imaging incorporating the modes safely usable and relatively simple in nature is required.

II. METHODOLOGY

Methodologies adopted are as follows:

1. A transillumination system upgraded to have different light frequencies to distinguish some tissue characters and boundaries.
2. By using ultrasound A mode at frequency of 20 MHz the boundaries are further defined.
3. A simple Scanning electrical impedance plethysmograph adapted for the subcutaneous imaging.
4. Moire topography for determining the surface shape combined with a bar code reader probe to obtain the distances between the grid lines automatically.
5. A measuring technique for skin thickness based upon assessment of differential flexural strengths by means of strain gauge transducers. With the help of the technique the

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skin thickness is determined to suitably incline the needle immediately after the skin puncture.

6. For feedback a strain gauge sensor is affixed to the base of the needle ensuring that there is no leakage.

7. A nine degree of freedom electro-mechanical actuator system to assist the surgeon's hand.

8. For the specific application for which the device is being developed a viscous liquid needs to be injected into the lumen of the vas deferens. Motorized or hydraulic based piston drive does not give the necessary "feel" required for correct injection. The force involved in free hand drive of the syringe piston leads to development of tremor in the surgeon's hand. Applying Independent Component Analysis (ICA), tremor is differentiated from voluntary movement. The tremor movements are suppressed by means of electromagnetic actuators driven in response to an inverse of the tremor signal.

9. An algorithm developed to coordinate the decisions based on the image and force data with the needle velocity and position.

III. DISCUSSION

Movement resolution required is of the order of 0.01 mm. An excess needle tip travel of 0.2 mm may lead to a counter puncture with spillage of drug outside the vas deferens. Also inspite of using a sharp tipped needle there is always an indentation in the wall of the vas deferens with a sudden "give" when the actual puncture occurs. The force application must quickly reduce at this time. Therefore time response is also an important parameter. The mechanical mass of a 9 degree of freedom actuator system makes obtaining the necessary speed difficult. Furthermore along with this issue the safety needs to be considered. In case of any subsystem failure the procedure has to be aborted safely.

The intra vas deferens injections are given under local anaesthesia. Subject movement is a possibility. The

system needs to "react" to the subject movement in such a manner that no adverse consequences ensue.

IV. CONCLUSION

A system model as yet without the features of safety under subsystem failure and on subject movement has been set up at a prototype level for dummy injection tests. The outer boundaries of the vas deferens can well be identified but as yet there are limitations in respect of visualization of the lumen and automated boundary detection. High electrical conductivity of the needle is a source of disturbance in the electrical impedance technique application. Moreover with the penetration of the needle into the wall of the vas deferens the lumen shape and size changes. There is a marked change in the lumen shape axially over a distance of about 2.5 mm. This distance is comparable to the bevel of the needle. Consequently accurate control over the entire needle bevel length becomes difficult. These issues are being addressed.

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